Modeling Report

WBID 2411 Sixmile Creek for
Nutrients and Dissolved Oxygen
Lower St. Johns River Basin

May 2013

Contents

Table of Figures

Table of Tables

US EPA ARCHIVE DOCUMENT

Watershed Description

The Sixmile Creek planning unit contains the Sixmile Creek tributary watershed east of the St. Johns River in St. Johns County. It covers approximately 122 square miles. Major tributaries include Trout Creek and Sixmile Creek, both of which join the St. Johns River independently, approximately 50 miles from the mouth. Mill Creek and Turnbull Creek are tributaries of Sixmile Creek.

WBID 2411 was listed as not attaining its designated uses on Florida's 1998 303(d) list for Nutrients and Dissolved Oxygen. Figure 1 provides the location of Sixmile Creek.
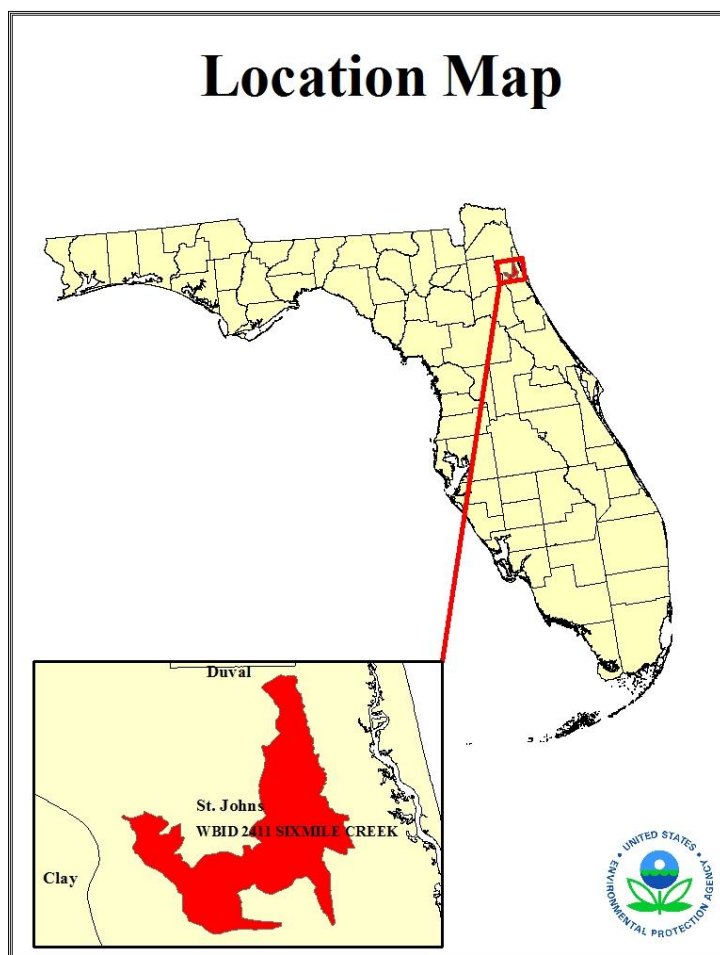
Figure 1 Location of Sixmile Creek Watershed and WBID

The landuse distributions for the Sixmile Creek watersheds are presented in Figure 2. The predominant landuse in the watershed is wetlands and upland forest.
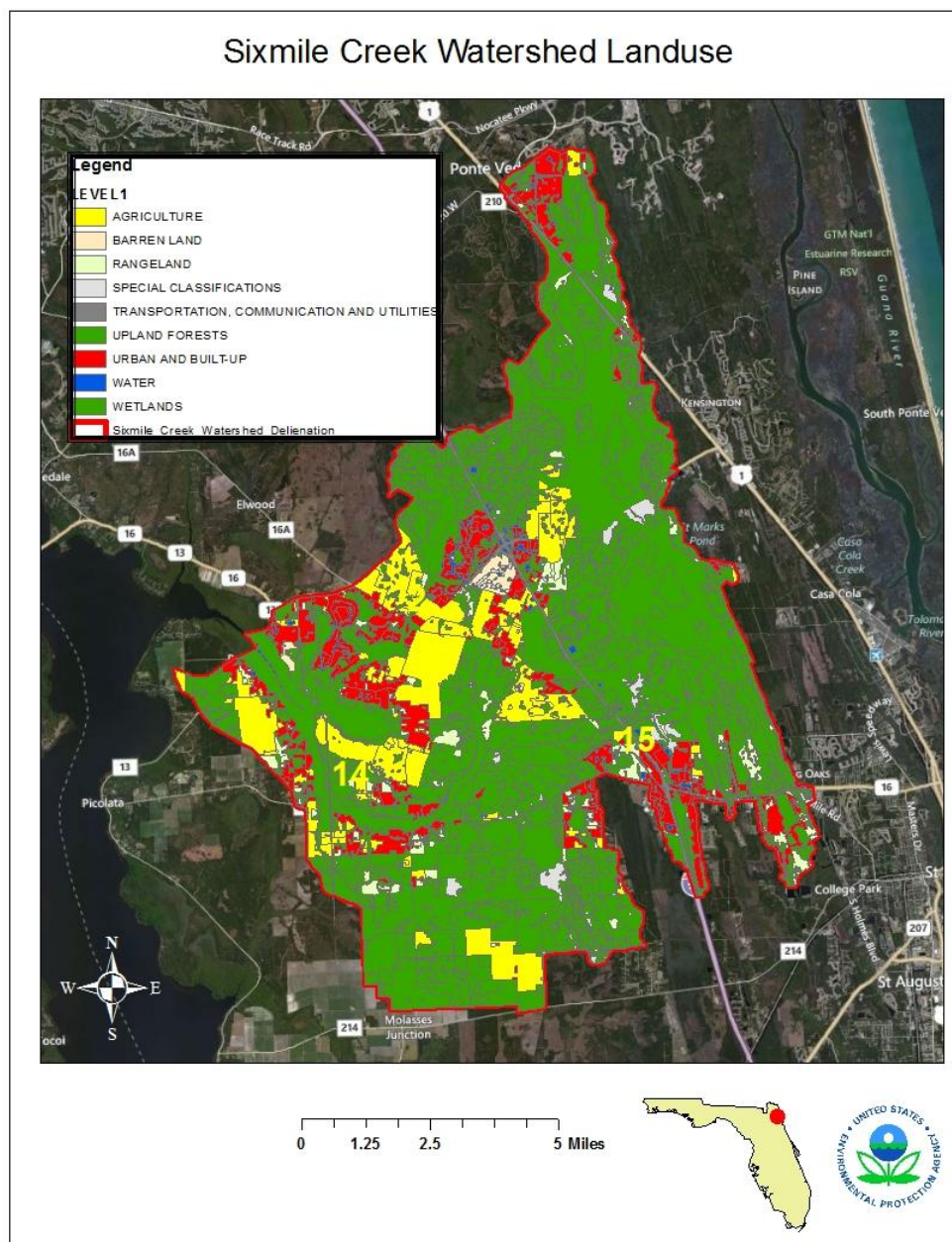
Figure 2 Landuse Distribution for Sixmile Creek Watershed

TMDL Targets

The TMDL reduction scenarios will be done to achieve a Florida's dissolved oxygen concentration of 5 mg/L and insure balanced flora and fauna within Sixmile Creek or establish the TMDL to be consistent with a natural condition if the dissolved oxygen standard cannot be achieved.

The waterbodies in the Sixmile Creek WBID are Class III Freshwater with a designated use of Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and

Modeling Report: WBID: 2411 Sixmile Creek – Nutrient/Dissolved Oxygen TMDL   November 2012

Wildlife. Designated use classifications are described in Florida's water quality standards. See Section 62-302.400, F.A.C. Water quality criteria for protection of all classes of waters are established in Section 62-302.530, F.A.C. Individual criteria should be considered in conjunction with other provisions in water quality standards, including Section 62-302.500 F.A.C., which established minimum criteria that apply to all waters unless alternative criteria are specified. Section 62-302.530, F.A.C. While FDEP does not have a streams water quality standard specifically for chlorophyll *a*, elevated levels of chlorophyll *a* are frequently associated with a violation of the narrative nutrient standard, which is described below.

Nutrients

The designated use of Class III waters is recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. In 1979, FDEP adopted a narrative criterion for nutrients. FDEP recently adopted numeric nutrient criteria for many Class III waters in the state, including streams, which numerically interprets part of the state narrative criterion for nutrients. While those criteria have been submitted to EPA for review pursuant to section 303(c) of the CWA, EPA has not completed that review. Therefore, for streams in Florida, the applicable nutrient water quality standard for CWA purposes remains the Class III narrative criterion.

Also, in November 2010, EPA promulgated numeric nutrient criteria for Class III inland waters in Florida, including streams. On February 18, 2012, the streams criteria were invalidated by the U.S. District Court for the Northern District of Florida and remanded back to EPA.

Narrative Nutrient Criteria

Florida's narrative nutrient criteria provide:

The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter. Man induced nutrient enrichment (total nitrogen and total phosphorus) shall be considered degradation in relation to the provisions of Sections 62-302.300, 62-302.700, and 62-4.242. Section 62-302.530(48)(a), F.A.C.

In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Section 62-302.530(48)(b), F.A.C.

Chlorophyll and dissolved oxygen (DO) levels are often used to indicate whether nutrients are present in excessive amounts. The target for this TMDL is based on levels of nutrients necessary to prevent violations of Florida's DO criterion, set out below.

Florida's adopted numeric nutrient criteria for streams

Florida's recently adopted numeric nutrient criteria interprets the narrative water quality criterion for nutrients in paragraph 62-302.530(48)(b), F.A.C. See section 62-302.531(2). The Florida

3 | P a g e

US EPA ARCHIVE DOCUMENT

rule provides that the narrative water quality criteria for nutrients in paragraph 62-302.530(47)(a), F.A.C., continues to apply to all Class III waters. See section 62-302.531(1).

Florida's recently adopted rule applies to streams, including (WBID in TMDL). For streams that do not have a site specific criteria, Florida's rule provides for biological information to be considered together with nutrient thresholds to determine whether a waterbody is attaining 62-302.531(2)(c), F.A.C. The rule provides that the nutrient criteria are attained in a stream segment where information on chlorophyll a levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicates there are no imbalances in flora and either the average score of at least two temporally independent SCIs performed at representative locations and times is 40 or higher, with neither of the two most recent SCI scores less than 35, or the nutrient thresholds set forth in Table 1 below are achieved. See section 62-302.531(2)(c).

Florida's rule provides that numeric nutrient criteria are expressed as a geometric mean, and concentrations are not to be exceeded more than once in any three calendar year period. Section 62-302.200 (25)(e), F.A.C.

Table 1. Inland Numeric Nutrient Criteria

Nutrient Watershed Region	Total Phosphorus Nutrient Threshold	Total Nitrogen Nutrient Threshold
Panhandle West	0.06 mg/L	0.67 mg/L
Panhandle East	0.18 mg/L	1.03 mg/L
North Central	0.30 mg/L	1.87 mg/L
Peninsular	0.12 mg/L	1.54 mg/L

West Central	0.49 mg/L	1.65 mg/L
South Florida	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.

Dissolved Oxygen Criteria

Numeric criteria for DO are expressed in terms of minimum and daily average concentrations. Section 62-302(30), F.A.C., sets out the water quality criterion for the protection of Class III freshwater waters as:

Shall not be less than 5.0 mg/l. Normal daily and seasonal fluctuations above these levels shall be maintained.

Natural Conditions

In addition to the standards for nutrients, DO and BOD described above, Florida's standards include provisions that address waterbodies which do not meet the standards due to natural background conditions.

Florida's water quality standards provide a definition of natural background:

"Natural Background" shall mean the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered waterbody may be based upon a similar unaltered waterbody or on historical pre-alteration data. 62-302.200(15), FAC.

Florida's water quality standards also provide that:

Pollution which causes or contributes to new violations of water quality standards or to continuation of existing violations is harmful to the waters of this State and shall not be allowed. Waters having water quality below the criteria established for them shall be protected and enhanced. However, the Department shall not strive to abate natural conditions. 62-302.300(15) FAC

Biochemical Oxygen Demand Criteria

Biochemical Oxygen Demand (BOD) shall not be increased to exceed values which would cause dissolved oxygen to be depressed below the limit established for each class and, in no case, shall it be great enough to produce nuisance conditions. [FAC 62-302.530 (11)]

Modeling Approach

The modeling approach that was used for the development of the nutrient and dissolved oxygen TMDL for Sixmile Creek considers 13 years of meteorological and flow conditions. The selection of a longer term continuous simulation insures that average, wet and dry conditions are considered in the TMDL determination. The modeling approach uses a dynamic watershed model that predicts surface runoff of pollutants (nitrogen, phosphorus and BOD) and flow as function of landuse and meteorological information. The 13 year simulation of watershed loadings and flow are fed forward to a water quality model that predicts the impacts of the loadings and flow on water quality in waterbody. The water quality model predicts: dissolved oxygen, nitrogen (ammonia, nitrate, and organic nitrogen), phosphorus (orthophosphate, organic phosphorus), chlorophyll a, biochemical oxygen demand as a function of loads and flows provided by the watershed model.

LSPC Watershed Model

The Loading Simulation Program C++ (LSPC) as the watershed model. LSPC is the Loading Simulation Program in C++, a watershed modeling system that includes streamlined Hydrologic Simulation Program Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream fate and transport model. LSPC is derived from the Mining Data Analysis System (MDAS), which was originally developed by EPA Region 3 (under contract with Tetra Tech) and has been widely used for TMDLs. In 2003, the U.S. Environmental Protection Agency (EPA) Region 4 contracted with Tetra Tech to refine, streamline, and produce user documentation for the model for public distribution. LSPC was developed to serve as the primary watershed model for the EPA TMDL Modeling Toolbox.

WASP Water Quality Model

Water Quality Analysis Simulation Program (WASP 7.5) (USEPA, 2011) is a generalized framework for modeling contaminant fate and transport in surface waters. Its flexible, compartmental approach allows it to address problems in one, two, or three dimensions. It is designed to allow easy substitution of user-written routines into the program structure. WASP has been used to answer questions regarding biochemical oxygen demand, dissolved oxygen dynamics, nutrients and eutrophication, bacterial contamination, and organic chemical and heavy metal contamination.

The WASP model integrates the predicted flows and loads from the LSPC model to simulate water quality responses in: nitrogen, phosphorus, chlorophyll a and dissolved oxygen. Both LSPC and WASP will be calibrated to current conditions, a natural condition. The WASP model will be used to determine the percent reduction in loadings that would be needed to meet water quality standards.

LSPC Application to Sixmile Creek Watershed

The watershed model was applied to the Sixmile Creek watershed model for the simulation period of 1996 through 2009. The 1996 year was used to equilibrate the initial conditions in the watershed model (soil moisture, buildup and washoff), from 1997 through 2009 was used to predict flows and loads under current conditions that will be passed onto the water quality model.

Watershed Delineation and Landuse

The surrounding watershed that drains directly to Sixmile Creek WBID was included in the watershed model. This encompasses land areas outside the delineated Sixmile Creek WBID. The watershed was delineated into 3 sub basins (Figure 3). The LSPC model will predict flow and loads coming from each of these sub basins into Sixmile Creek.

Figure 3. Sixmile Creek Watershed Delineation

The initial model setup for Sixmile Creek was obtained from EPA's application of LSPC for the purposes of nutrient criteria development; the model was further refined and calibrated to all local data and gages that were available in the watershed.

Landuse coverage was obtained from the St. Johns River Water Management District (Florida Landuse Classification Code) coverage developed from 2004 (See Figure 2). Table 2 provides the landuse distribution for each of the 3 sub basins being modeled.

Table 2 Landuse Distribution for Sub Basins

Subbasin Name	Agriculture	Barren Land	Rangeland	Special Classifications	Transportation, Communication And Utilities	Upland Forests	Urban And Built-Up	Water	Wetlands	Totals
14	2717.3	74.2	425.2	99.3	54.3	7051.1	1422	65.1	2619.3	14527.8
15	1738.9	40.7	1053.7	594.6	463.4	12981	2827.4	256.8	14409.1	34365.5
2	1818.9	202.3	108.1	68.6	140.1	1903.6	1712.8	202	2844.8	9001.4

Meteorological Information

Non-point source loadings and hydrological conditions are dependent on weather conditions. Hourly data from weather stations within the boundaries of, or in close proximity to the sub-watersheds were applied to the watershed model. An ASCII file (*.air) was generated for each meteorological and precipitation station used for the hydrologic evaluations in LSPC. Each meteorological and precipitation station file contains atmospheric data used for modeling of the hydrologic processes. These data include precipitation, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation. These data are used directly, or calculated from the observed data.

Figure 4 depicts the hourly rainfall for the St.Augustine (087826) meteorological station. The period of record being simulated during this TMDL development contains average, wet and dry years.
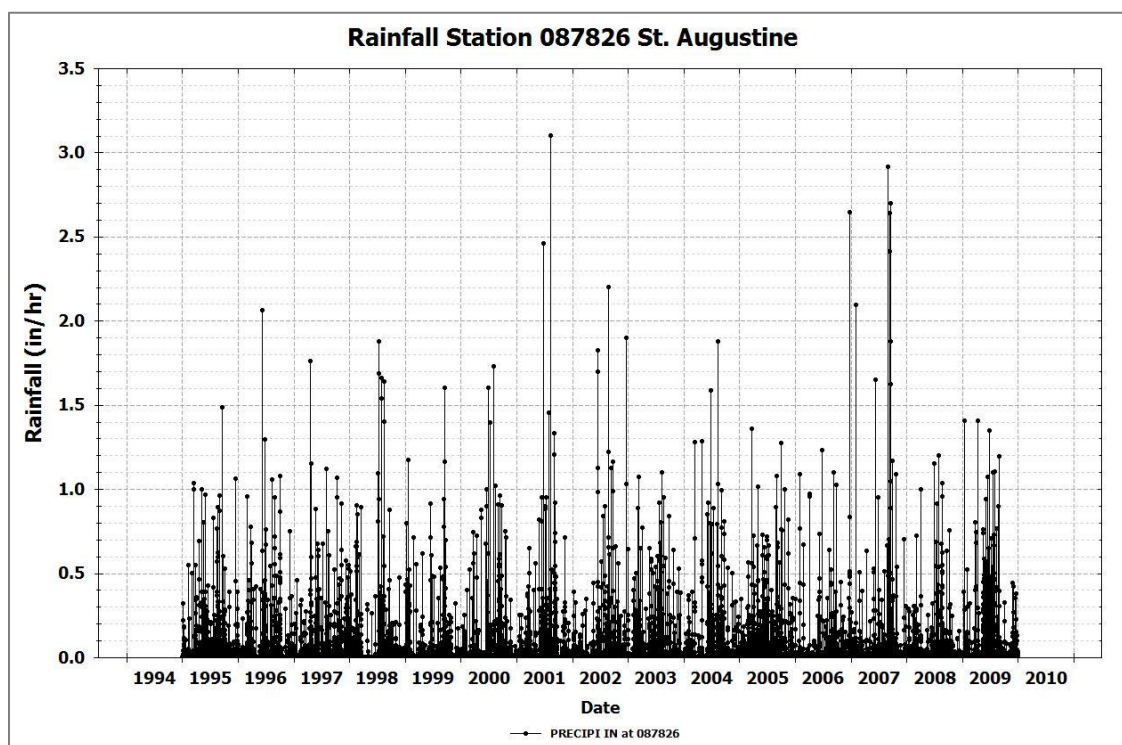

Figure 4. Hourly Rainfall Station 083137

Table 3 provides the annual rainfall for each of the simulation years.

Table 3. Annual Rainfall for Simulation Period

Date & Time	Rainfall (inches)
1996	53.1
1997	53.73
1998	57
1999	47.04
2000	39.99
2001	44.23
2002	57.22
2003	54.22
2004	52.24
2005	50.06
2006	70.05
2007	37.38
2008	58.02
2009	42.94
2010	59.44

Hydraulic Calibration

The watershed and water quality model were calibrated for flow by comparing the predict flows to the USGS gage 0225315. Figure 5 illustrates both a quantitative and qualitative comparison of the model flow predictions directly compared to the measurements at the USGS gage.
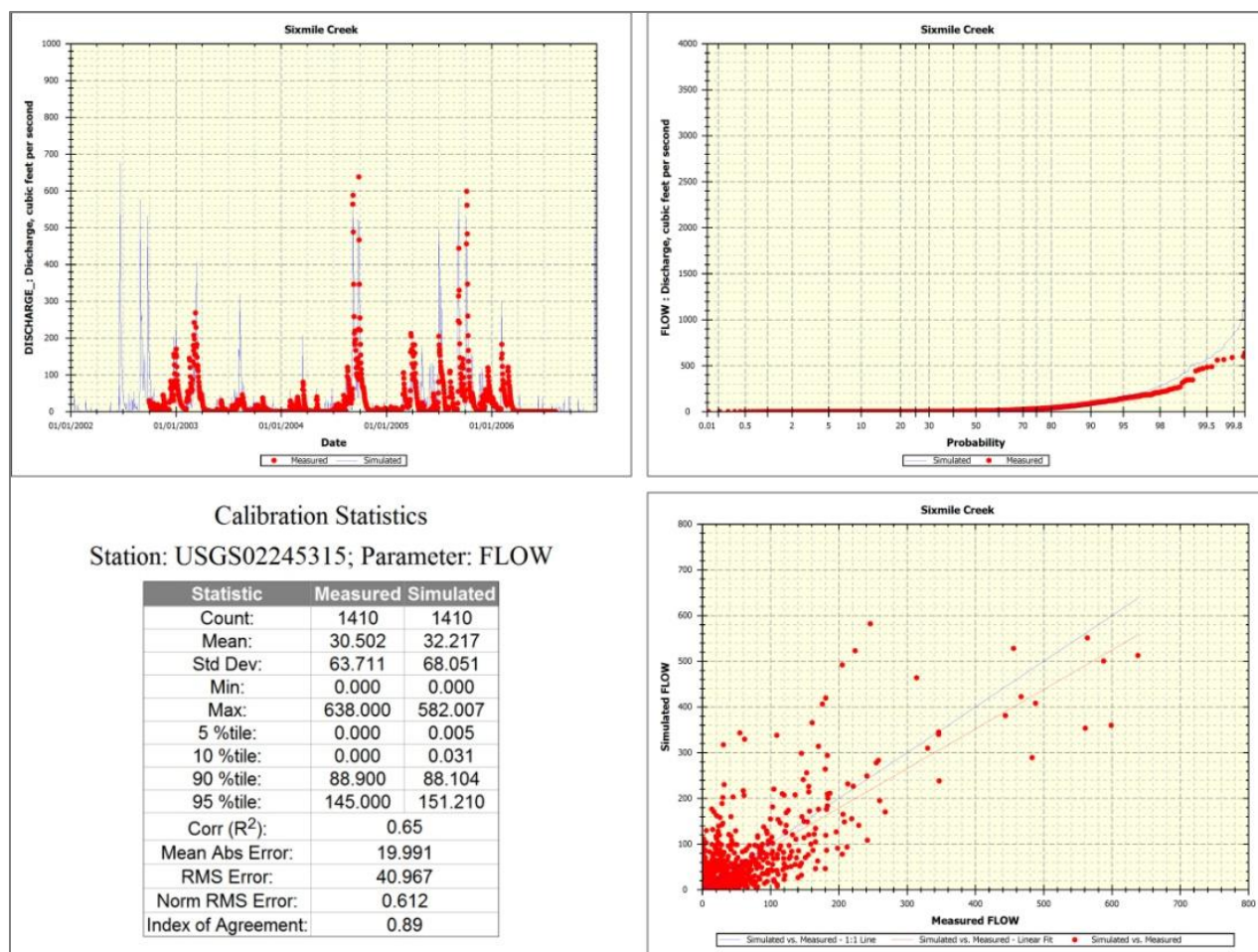
Figure 5. Flow Calibration for Sixmile Creek Watershed

Water Quality Model Application

The WASP water quality model uses the kinematic wave equation to simulate flow and velocity and the basic eutrophication module to predict dissolved oxygen and Chlorophyll a responses to the BOD, total nitrogen and total phosphorus loadings.   The waterbody geometry was determined from NHDPlus coverages of the free flowing stream sections.

Model Network

The Sixmile Creek waterbody was broken into segments for the water quality model. The model segmentation was done based upon the NHDPlus coverage taking into account travel time, pore points for the watershed model and IWR monitoring stations.

Figure 6 illustrates the 10 water quality model segments that are simulated. The LSPC model flows and loads enter the water quality model at segments 7 and 10.
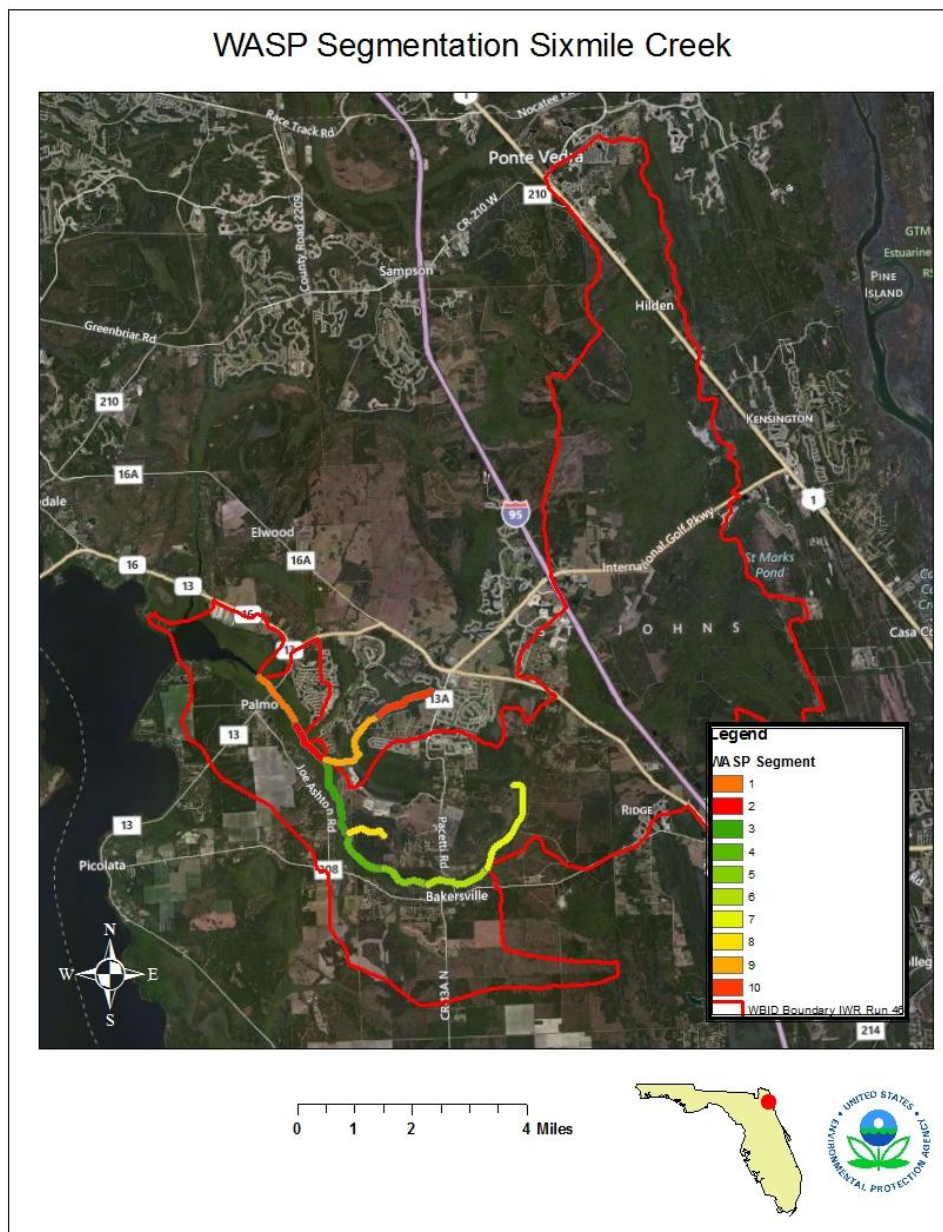
Figure 6. WASP Model Segmentation

Water Quality Model Calibration

The water quality model was calibrated to all available data. The fine tuning of the calibration of the model utilized the IWR station located at the lower end of the WBID that most of the monitoring data.

Table 4 provides a listing of the IWR stations that were used to calibrate the WASP model. All stations that had nutrient, BOD, dissolved oxygen and chlorophyll a measurements were used in the calibration process. The station highlighted in yellow was used for the water quality.

Table 4. Impaired Waters Rule Database Stations used in Water Quality Model Calibration Sixmile Creek Creek

Station	Station Name	First Date	Last Date	No. Obs
21FLA 20030966	ST JOHNS RIVER @ PALMO COVE	5/19/2011 10:35	6/5/2012 10:38	42
21FLA 20030996	SIXMILE CR AT 208	3/29/2012 11:55	3/29/2012 11:55	13
21FLBRA 2411-A	2411 - Sixmile Creek - marina on CR 13	4/21/2008 14:55	6/18/2008 9:56	24
21FLBRA 2411-B	2411 - Sixmile Creek - Bridge on Pacetti Rd	4/21/2008 15:50	6/18/2008 10:50	9
21FLBRA 2411-C	2411 - Sixmile Creek - culvert on CR 208	5/1/2008 9:50	6/23/2008 13:58	15
21FLBRA 2411-D	2411 - Sixmile Creek - Box culvert on Joe Ashton Rd	6/18/2008 10:14	6/23/2008 13:50	6
21FLBRA 2411-E	2411 - Sixmile Creek - Bridge on Hwy 16	6/18/2008 11:36	6/23/2008 13:05	6
21FLSJWMSMC	Sixmile Creek at SR 13	7/13/2004 9:50	9/7/2011 12:20	907

Table 5 provides a comparison of predicted annual average concentrations versus the annual average concentrations of the measured data. While it is important to capture seasonal variation, duration and frequency of water quality, it is very critical to approximate average conditions in the system. It is during these periods of times that nutrients are expressed.

Table 5. Predicted vs. Observed Annual Average Concentrations

Constituent	Simulated	Observed
BOD (mg/L)	2.19	2.05
Chlorophyll a (ug/L)	8.50	11.15
DO (mg/L)	4.93	4.44
Total Nitrogen (mg/L)	1.13	1.07
Total Phosphorus (mg/L)	0.11	0.11

Figure 7 through **Error! Reference source not found.** provide calibration comparison for all of the major water quality constituents in which data is available.

Water Temperature

Water temperature is simulated in the water quality because of its influence on degradation, kinetic transformation, algal growth and decay rates. Because several modeling scenarios will be simulated, such as a natural condition, an estimate of water temperature under this condition could be important.

Figure 7 illustrates both a quantitative and qualitative comparison of the simulated water temperature compared to the direct measurements.
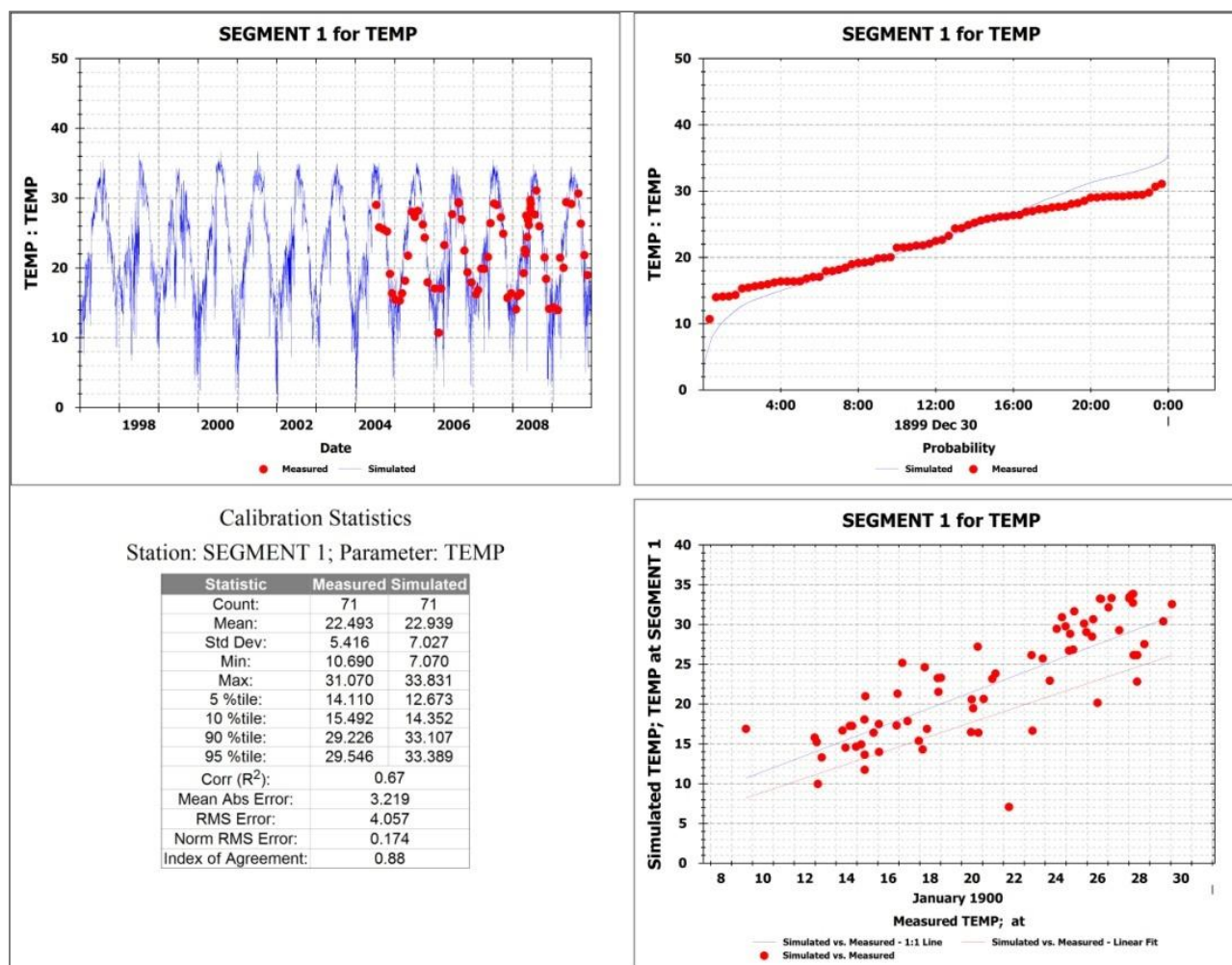
Figure 7. Water Temperature Calibration Segment 1

Dissolved Oxygen

The dissolved oxygen calibration will be important in the development of this TMDL because it will be the primary response variable to determine the reductions.

Figure 8 illustrates both a quantitative and qualitative comparison of the predicted dissolved oxygen concentrations compared to the direct measurements.
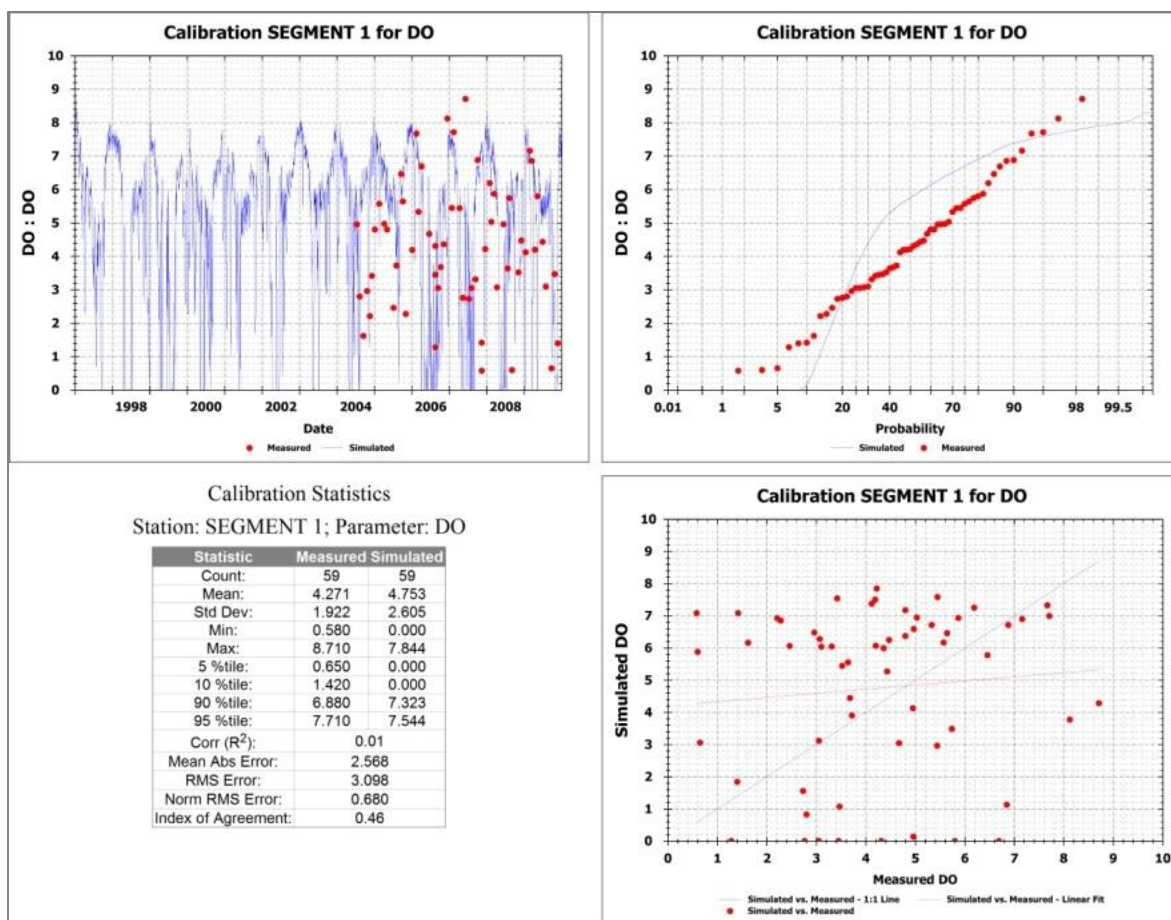
Figure 8. Dissolved Oxygen Calibration

Biochemical Oxygen Demand

The following presents BOD data that is available from the IWR Station. Most of the values are at detection limit.

Figure 9 illustrates both a quantitative and qualitative comparison of the predicted dissolved oxygen concentrations compared to the direct measurements.

Figure 9. BOD Calibration Segment 3

Chlorophyll a

The following presents chlorophyll a data that is available from the IWR Station. Figure 10 illustrates both a quantitative and qualitative comparison of the predicted dissolved oxygen concentrations compared to the direct measurements.
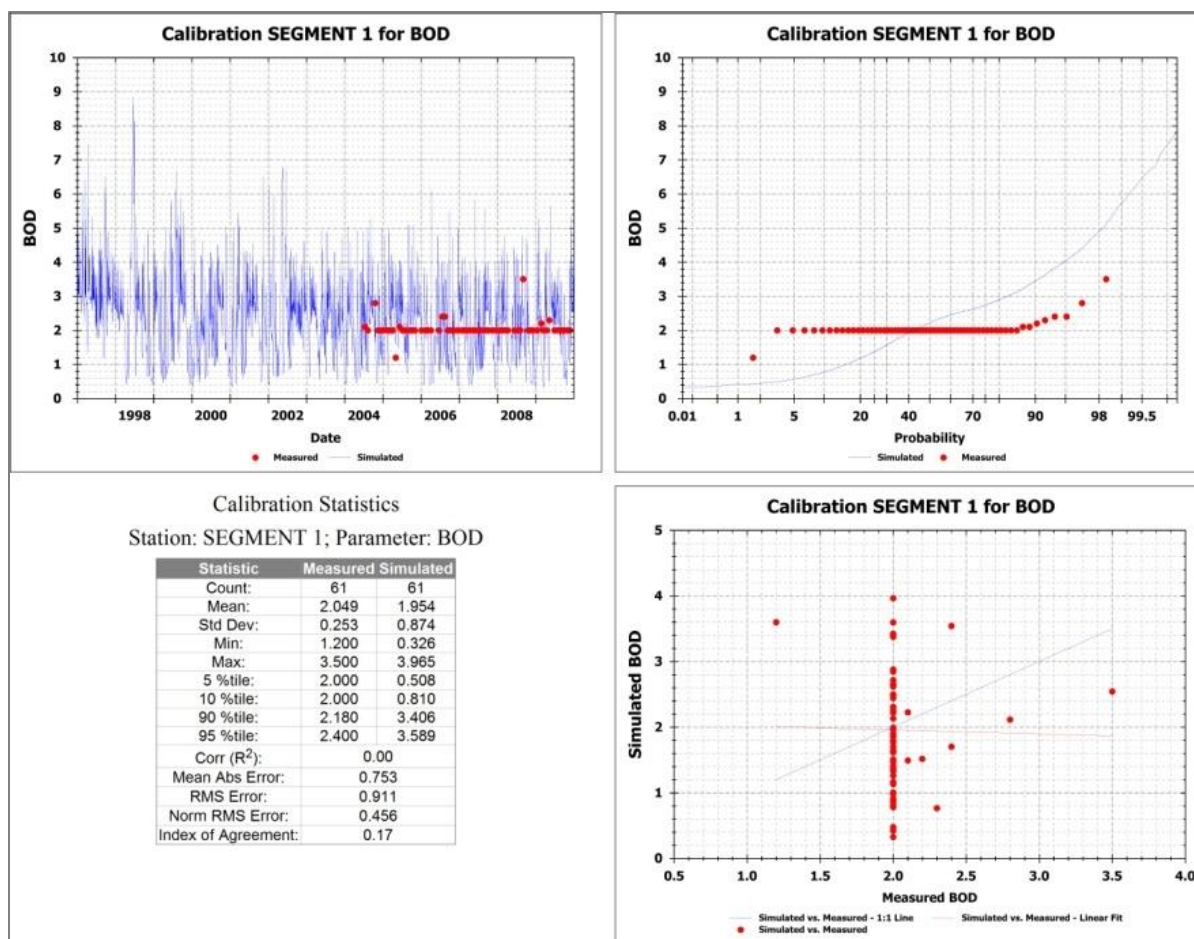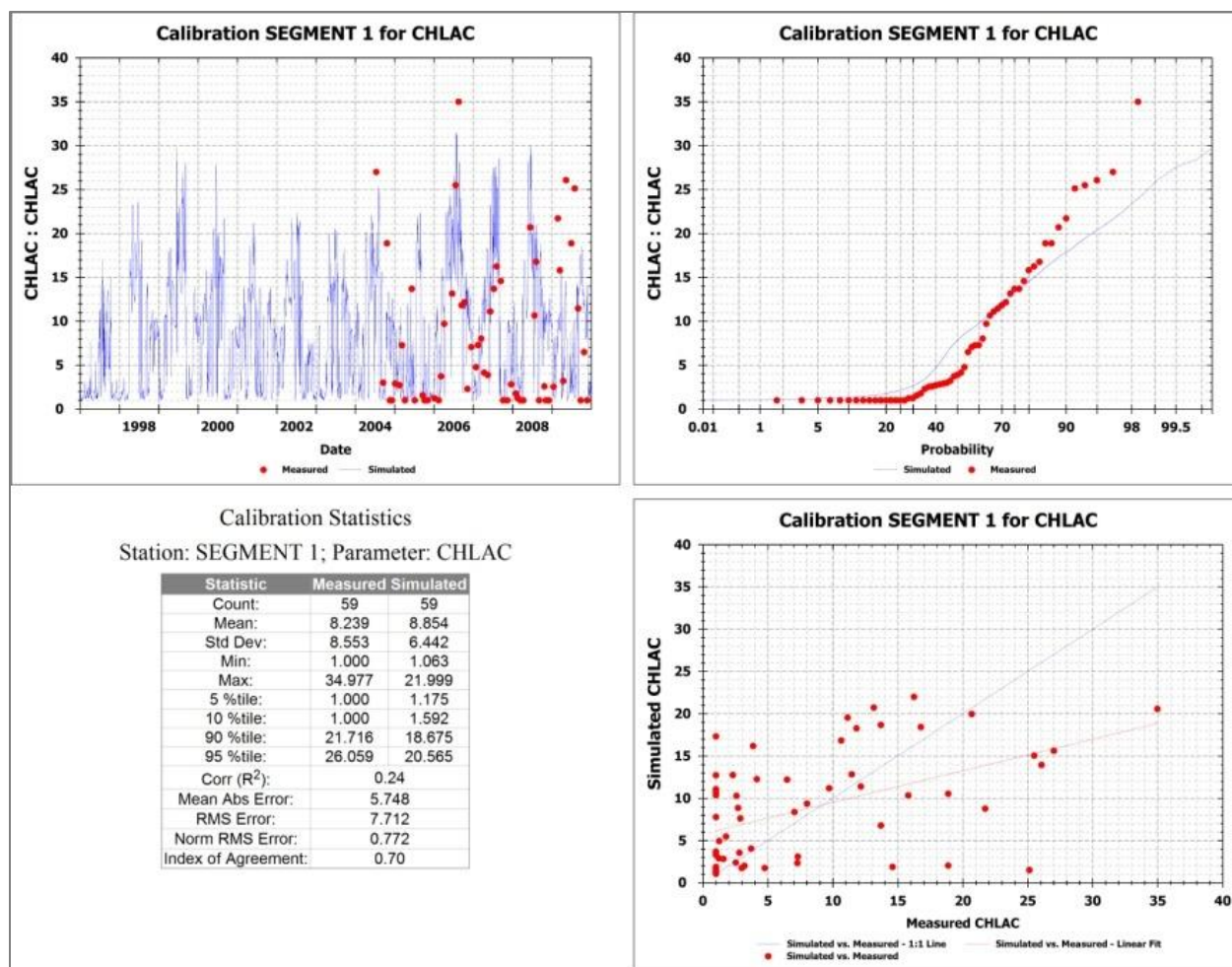
Figure 10. Chlorophyll a Calibration

Nitrogen

Figure 11 illustrates both a quantitative and qualitative comparison of the model predictions for total nitrogen to direct measurements.
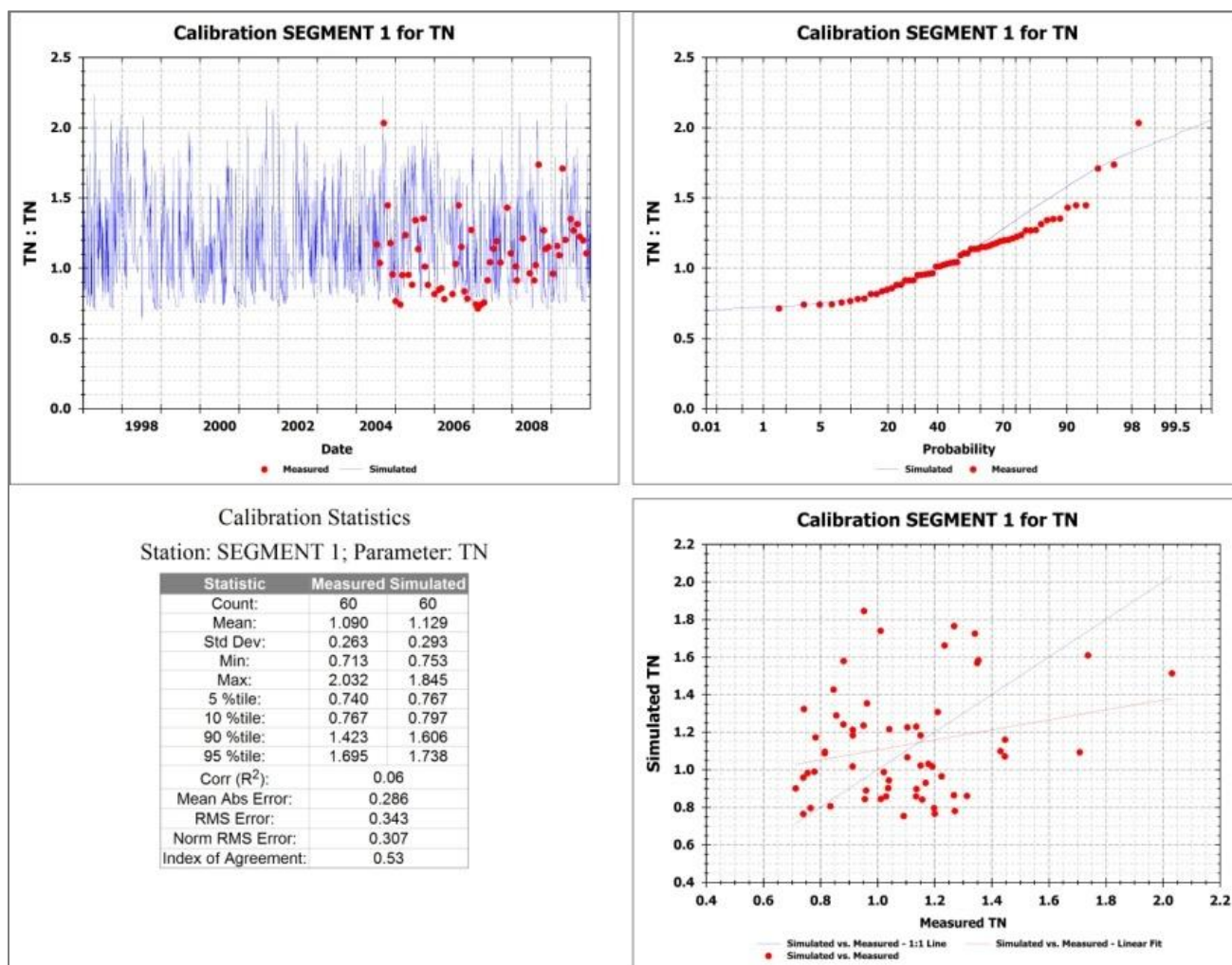
Figure 11. Total Nitrogen Calibration Segment 3

Phosphorus

Figure 12 illustrates both a quantitative and qualitative comparison of the model predictions for total phosphorus to direct measurements.
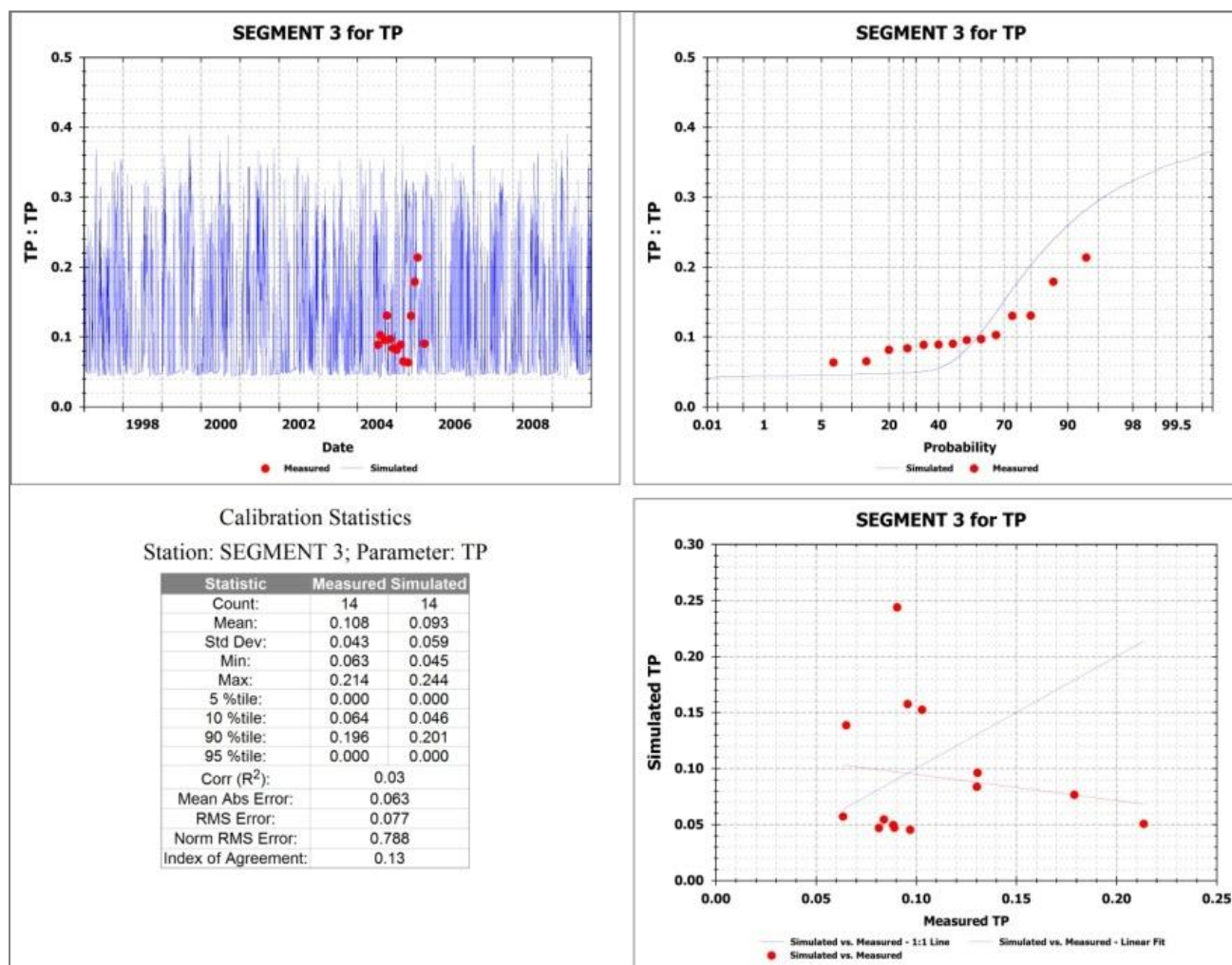
Figure 12. Total Phosphorus Calibration Segment 3

Current Loads

Table 4 provides the annual average total nitrogen, total phosphorus and BOD loads for the period of record 1997 through 2009. It is these loadings that the TMDL load reduction will be calculated from.

Table 6. Current Loads (1997-2009)

	Current Condition	
Constituent	WLA (kg/yr)	LA (kg/yr)
BOD	NA	287,919
Total Nitrogen	NA	142,199
Total Phosphorus	NA	15,473

Modeling Scenarios

Using the calibrated watershed and water quality models, up to two potential modeling scenarios will be developed. The first scenario will be to predict water quality conditions under a natural condition (remove point sources and returning landuses back to upland forests and wetlands). A second scenario will be developed if water quality standards can be met under natural conditions (balanced flora and fauna, dissolved oxygen greater than 5 mg/L); loads would be reduced from the current conditions until standards are met (balanced flora and fauna, dissolved oxygen greater than 5 mg/L)

Natural Condition Analysis

The purpose of the natural condition scenario is to determine the water quality in the Sixmile Creek watershed without the influences of man. Because of Florida's regulation of not allowing abating of a natural condition, this scenario determines the maximum reduction that could be required. The natural condition scenario makes the following assumptions:

1. All man induced landuses in the watershed model are transformed back to wetlands and upland forest (50:50).
2. New hydrology is predicted under natural landuse assumption.
3. All point sources are removed (if any).
4. Water quality is predicted using the new flows and loads from the natural condition run from the watershed model.
5. Sediment oxygen demand is reduced based upon the percent reduction in nutrient loads.

Table 7 presents the predicted annual average concentrations under natural conditions. Without the impacts of anthropogenic sources the dissolved oxygen concentration in the Sixmile Creek watershed. It should be noted that under natural conditions the dissolved oxygen standard of 5 mg/l would not be achieved. The natural condition scenario will be used to set the maximum loads for the TMDL.

Table 7. Natural Condition Annual Average Model Predictions

Constituent	Natural
BOD (mg/L)	1.06
Chlorophyll a (ug/L)	8.12
DO (mg/L)	5.80
Total Nitrogen (mg/L)	0.87
Total Phosphorus (mg/L)	0.05

Table 8 provides the annual average model predictions for total nitrogen, total phosphorus, and dissolved oxygen under a natural condition.

Table 8. Annual Average Loadings for Natural Condition

Natural Condition		
Constituent	WLA (kg/yr)	LA (kg/yr)
BOD	NA	118,641
Total Nitrogen	NA	84,045
Total Phosphorus	NA	4,460

Figure 13 shows the probability distribution for dissolved oxygen concentration in Sixmile Creek under current and the natural condition scenario.
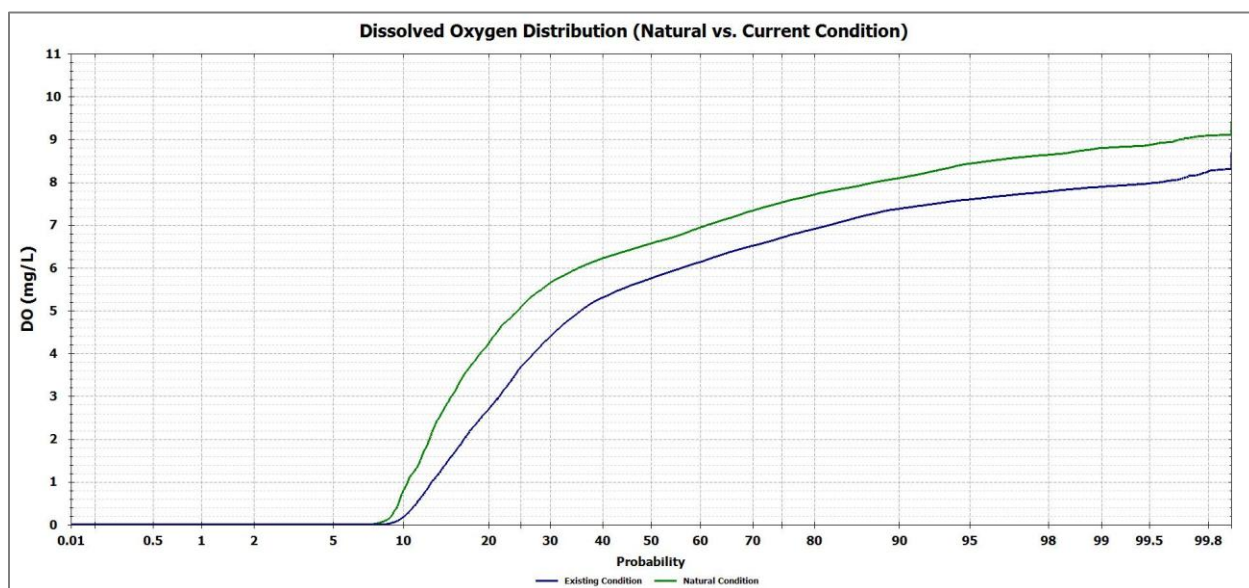

Figure 13. Dissolved Oxygen Concentration Probability Current vs. Natural Condition

Figure 14 shows the time series plot of dissolved oxygen concentration in Sixmile Creek under the natural condition scenario.
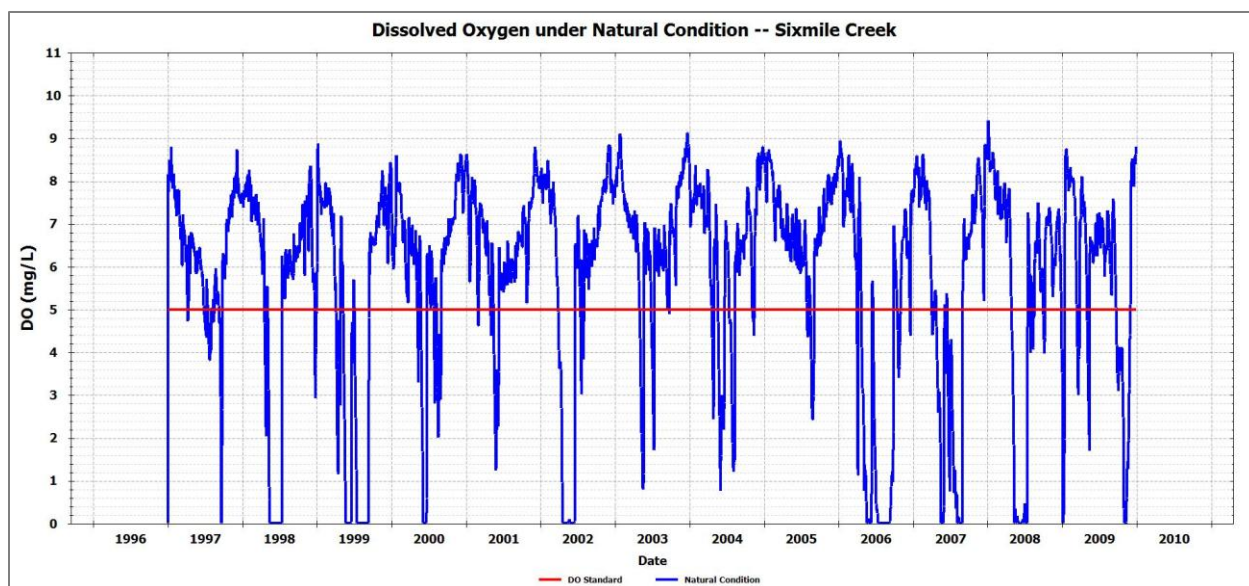
Figure 14. Dissolved Oxygen Concentration under Natural Condition

TMDL Load Reductions

Because water quality standards cannot be met under natural conditions no other scenarios were conducted. The TMDL will be set to the natural conditions.

TMDL Determination

The TMDL load reduction was determined by reducing the current conditions to the natural conditions. The annual average loadings are given in Table 9 along with the prescribed load reductions.

Table 9. TMDL Determination

	Current Condition		TMDL Condition		MS4	LA
Constituent	WLA (kg/yr)	LA (kg/yr)	WLA (kg/yr)	LA (kg/yr)	% Reduction	% Reduction
BOD	NA	287,919	NA	118,641	59%	59%
Total Nitrogen	NA	142,199	NA	84,045	41%	41%
Total Phosphorus	NA	15,473	NA	4,460	71%	71%

Note: Both the watershed and water quality models including calibration and scenario input files are available upon request.